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HOSPITAL POLICY AND PRODUCTIVITY: EVIDENCE FROM GERMAN STATES

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Hospital Policy and Productivity: Evidence from German States*

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Abstract

Total factor productivity (TFP) growth allows for additional health care services under restricted resources. We examine whether hospital policy can stimulate hospital TFP growth. We exploit variation across German federal states in the period 1993 to 2013. State governments decide on hospital capacity planning (number of hospitals, departments and beds), ownership, medical students, and hospital investment funding. We show that TFP growth in German hospital care reflects quality improvements rather than increases in output volumes. Second-stage regression results indicate that reducing the length of stay is generally a proper way to foster TFP growth. The effects of other hospital policies depend on the reimbursement scheme: under activity-based (DRG) hospital funding, scope-related policies (privatization, specialization) come with TFP growth. Under fixed daily rate funding, scale matters to TFP (hospital size, occupancy rates). Differences in capitalization in East and West Germany allows to show that deepening capital may enhance TFP growth if capital is scarce. We also show that there is less scope for hospital policies after large-scale restructurings of the hospital sector.

JEL classification: I11; I18; O47

Keywords: Hospitals; TFP; Productivity; Policy; Germany

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1. Introduction

If health care outputs increase more than inputs, i.e., total factor productivity (TFP) grows, additional health services or shorter waiting times can be provided even under restricted resources (Bojke *et al.*, 2016). In this paper, we study the role of hospital policy in stimulating hospital TFP growth. Governments specialize, privatize, and enlarge hospitals, presuming to increase hospital productivity (Blank and Valdmanis, 2008; Productivity Commission, 2009; Carter, 2015). Little is known, however, whether these policies actually stimulate TFP. Previous studies focus on hospital funding only (Dismuke and Sena, 1999; Linna, 1999; Sommersguter-Reichmann, 2000; De Castro Lobo *et al.*, 2010; Castelli *et al.*, 2015). As a sole exception, Blank and Eggink (2014) link time series in Dutch hospital productivity to different periods of hospital regulation and show that productivity was somewhat higher in times of stronger competition.

Our setting is different. We exploit variation in hospital policies and hospital TFP growth across German federal states in the period 1993 to 2013. German state governments decide on hospital capacity planning, ownership, medical students, and hospital investment funding, while the central government is limited to setting the financial framework. We show that TFP growth in German hospital care reflects quality improvements rather than increases in output volumes. Second-stage regression results show that reducing the length of stay is generally a proper way to foster hospital TFP growth. The effects of other policies depend on the reimbursement scheme: under activity-based hospital funding, privatization and specialization come with TFP growth. Under fixed daily rate reimbursement, TFP growth accompanies increases in hospital size and in occupancy rates. Public investment funding and training medical students seem not to affect hospital TFP growth. We elaborate on East and West Germany separately. In West Germany, capital is scarce and substituting labor by capital enhances TFP growth. Non-findings for the entirely restructured and modernized hospital sector in East Germany after re-unification indicate that there is less scope for hospital policies after large-scale reforms.

This study adds further aspects to the literature. First, we document substantial long run differences in regional hospital productivity growth and policy. Previous studies show regional variation in health care supply (e.g., Skinner, 2012, Kopetsch and Schmitz, 2014, Finkelstein *et al.*, 2016), but only few cross-sectional studies focus on regional differentials in the productivity of health services (Schleiniger, 2008; Bojke *et al.*, 2013). We rely on a rich panel dataset covering German hospital development of about 20 years. This allows us to exploit temporal differences in regional TFP growth rates. Second, our study bridges hospital-level TFP studies (seminally Färe *et al.*, 1994a; for an overview see Hollingsworth, 2008)[1] and studies using national accounts (Cromwell and Pope, 1989; Cylus and Dickensheets, 2008; Harper *et al.*, 2010; Gu and Morin, 2014). Being the sole exceptions, de Nicola *et al.* (2013) and Aragon Aragon *et al.* (2015) examine productivity at the regional level. We exploit policy and productivity differences across regions; the 16 German federal states (*Bundesländer*) constitute our decision-making units of interest. Regional aggregation allows to use considerably more precise measures than at the hospital level (e.g., capital stocks).[2] Aggregated data also internalize spatial correlations between hospitals arising from patient transfers, geography and socio-demographic idiosyncrasies (Baltagi and Yen, 2014) to large extent. We use two different TFP measures which allows us to decompose output growth into TFP and input growth contributions (Törnqvist index), and to further decompose TFP growth into efficiency and technological change (Malmquist index). Few general productivity studies (Färe *et al.*, 1994b; Kim and Park, 2006) and no health care-related study have applied both Törnqvist and Malmquist TFP. Third, only few hospital TFP studies use a second-stage regression to examine drivers of productivity (Dimas *et al.*, 2012, Castelli *et al.*, 2015). The panel structure of our dataset allows us to control for socio-demographic control variables, state fixed effects and time fixed effects in order to isolate sources of hospital TFP growth more precisely.

2. Hospital policy in Germany

In Germany, hospital policy is shared among the central government and the 16 state governments. The central government is limited to setting the financial framework, in particular, designing hospital reimbursement schemes for current expenditures. As the most important hospital reform among the last decades, the central government changed hospital reimbursement from fixed daily (*per diem*) rates to activity-based financing (DRG) nationwide in 2004. State governments, by contrast, decide on hospital capacity plans, allocate funds on hospital investments, run university hospitals, and train medical students (Wassener, 2002; Bremner, 2011; Ettelt *et al.*, 2012; Mätzke, 2013). German state governments thus "play an active part in day-to-day health policy" (Wassener, 2002, p. 99).

We identify six different policies of state governments which may have an effect on hospital productivity (see Figure 1). First, ownership may matter to productivity. Privatization of hospitals is mentioned as a

[1] Recent hospital TFP studies are, e.g., Barros *et al.* (2008), Gannon (2008), de Castro Lobo *et al.* (2010), Ng (2011), Dimas *et al.* (2012), and Castelli *et al.* (2015). For further studies and a synopsis see Table S.1 in the supplementary material.

[2] In the context of productivity studies, aggregation should be carried out with caution. Aggregation may not only lead to a substantial loss in variation but also to ecological fallacies. In this study, however, state-level aggregates perfectly coincide with our decision-making units of main interest (state governments).

strategy to induce efficiency, even though evidence is mixed (Tiemann *et al.*, 2012). We use the state-level share of private for-profit hospitals to measure privatization,[3] yielding a spread from 0% (Saarland) to 70% (Hamburg) in 2013 (Figure 1 a), left-hand side). By contrast, the share of public hospitals decreases for decades (Figure 1 a), right-hand side). The hospitals remaining are private non-profit.

[Figure 1 about here]

Second, German state governments determine the number of hospitals, beds, and departments (hospital capacity planning). Some hospital plans even include the precise number of beds of all departments and all hospitals (either public, private for-profit, or private non-profit) within the state. Enlarging or stipulating hospital mergers may induce scale effects that in turn enhance productivity (Bazzoli, 2008; empirical evidence is mixed, see Gaynor *et al.*, 2012). The average hospital size varies substantially across the states, ranging from 170 beds per hospital (Schleswig-Holstein) to 370 beds per hospital (Thuringia) in 2013 (see Figure 1 b)).

Third, hospital capacity plans also describe the specialization of hospitals. Specialization may stimulate TFP if gains from expertise outweigh the economies of scope from joint production (Castelli *et al.*, 2015). We use the normalized Gini index of hospital beds in 18 hospital departments (state aggregates) (Figure 1 c)). The larger this index, the more the state hospital sector is specialized in a certain discipline, e.g., heart disease. Specialization decreases between 1993 and 2013 and, again, varies across states.

Fourth, German state governments allocate funds on hospital investment (Pilny, 2016). New technologies, financed by state investment funding, may increase hospital TFP growth. Figure 1 d) however shows that the state budget share for hospital investment funding decreases in all states between 1993 and 2013.

Fifth, German states determine the number of medical students in universities (Figure 1 e)). Training medical students consumes resources and may hamper TFP at least in the short run (Grosskopf *et al.*, 2001; Castelli *et al.*, 2015).

Sixth, shortening the average length of stay, increasing the occupation rate, and deepening capital are often mentioned as productivity enhancing strategies, but are mainly the responsibility of hospital managers. The left-hand and center graph of Figure 1 f) show that the average length of stay converges

[3] The number of small, medium and large private for-profit hospitals grew to the same extent as the number of beds in each subgroup. The number of hospitals thus captures the trend towards privatization well.

whereas occupation rates seems to diverge in Germany. Health policy can induce some pressure. The occupation rate depends on the number and spatial distribution of hospital beds which is a result of capacity planning. The length of stay is a key element in many hospital plans, e.g., in the state of Hesse (Section 17 of the Hessian hospital act). Though less visible, state politicians also exert informal pressure on hospitals. The mix of capital and labor is also mainly determined by hospital managers but depends on the legal and financial framework (e.g., construction and hygiene standards). Deepening capital has been shown to increase hospital TFP to some extent (Gu and Morin, 2014). Figure 1 f) (right-hand side) shows the capital intensity in three groups of German states. The sharp increase in capital intensity in the five East German states is a result of massive investments after the re-unification. Capital intensity increases steadily in the ten West German states. As an outlier, the once over-sized hospital sector in the formerly divided city of Berlin convergences toward the German average.[4]

Altogether, German states vary substantially in different aspects of hospital policy. In the remaining part of the paper, we study whether these differences translate into differences in hospital TFP growth. We also examine the party affiliation of the health minister. Left-wing parties favor equality and redistribution rather than competition, and run a larger public sector than their right-wing counterparts.[5] Left-wing health ministers may thus impose less pressure on hospitals than their right-wing colleagues. Previous studies show that spatial distribution of hospital beds is more equally distributed across German states that are governed by a left-wing party (Bennema-Broos *et al.*, 2001). We hypothesize that incentives to enhance productivity are lower under left-wing state health ministers.

3. Methods

We follow a two-stage strategy. In the first stage, we calculate the annual productivity change of the state hospital sector. We adopt the Malmquist and the Törnqvist indices. In the second stage, we use a fixed effects panel regression to reveal policies that coincide with productivity gains. We use state-level aggregates throughout the entire analysis.

3.1 Total factor productivity (TFP)

Total factor productivity change (TFP) refers to changes in outputs that cannot be attributed to shifts in inputs. We use two deterministic concepts in measuring TFP, representing a frontier (Malmquist index)

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[4] The division of Berlin induced a massive oversupply in hospital care because both the GDR and the Federal Republic of Germany run a full-sized hospital sector for each part of the city.
[5] Vatter and Rüefli (2003) and Herwatz and Theilen (2014) show higher health expenditures under left-wing governments. Potrafke (2010) however do not reveal significant partisan differences in health care expenditures.

and a non-frontier approach (Törnqvist index).[6] The Törnqvist index allows to decompose output growth into TFP and input growth contributions. The Malmquist index, by contrast, allows to decompose TFP growth into efficiency and technological change. Multiple decision-making units can be benchmarked by the index concept described by Malmquist (1953) (see Caves *et al.*, 1982; Färe *et al.*, 1994b). The (output-oriented) Malmquist index in period t is the ratio of two distance functions measuring the maximal proportional change of the input-output combination of the previous period (x_{t-1}, y_{t-1}) (denominator) and of the current period (x_t, y_t) (numerator), holding the production technology of a certain point of time constant. Malmquist TFP, TFP_t^{MQ}, is the geometric mean of two Malmquist indices for the production technology in period $t-1$ and t:[7]

$$TFP_t^{MQ} = \ln MQ_t(x_t, y_t, x_{t-1}, y_{t-1}) = \ln\left[\left(\frac{D_{t-1}(x_t, y_t)}{D_{t-1}(x_{t-1}, y_{t-1})}\right)\left(\frac{D_t(x_t, y_t)}{D_t(x_{t-1}, y_{t-1})}\right)\right]^{\frac{1}{2}} \tag{1}$$

We use the data envelopment analysis (DEA) to compute Malmquist productivity indices. This allows to decompose MQ_t into changes in efficiency (EFFCH) and into a frontier effect (TECHCH). The non-frontier index concept of Törnqvist (1936) can be derived as a special case of the Malmquist index (Färe *et al.*, 1994b) and is roughly equivalent to the growth accounting framework of Solow (1957). We assume a Cobb-Douglas production function and compute the Törnqvist TFP by logarithmic transformation. The Törnqvist TFP can be written as the difference of (logarithmic computed) output growth rates and cost share-weighted[8] input growth rates:

$$TFP_t^{TQ} = \ln\left(\frac{y_t}{y_{t-1}}\right) - \sum_{n=1}^{N} \alpha_{n,t} \ln\left(\frac{x_{n,t}}{x_{n,t-1}}\right) \tag{2}$$

3.2 Inputs and outputs

Output. Studies on hospital TFP vary substantially in outputs and inputs (for a synopsis, see Table S.1 in the supplementary material).[9] We run separate TFP calculations for three different output measures:

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[6] Econometric and thus non-deterministic approaches such as the Stochastic Frontier Analysis (SFA) control for random shocks but rely on a large set of econometric assumptions (Del Gatto *et al.*, 2011). Because we investigate data at the state level, idiosyncratic shocks to productivity at the hospital level are internalized to large extent, and econometric methods are not adequate for our study design.

[7] Färe *et al.* (1994b) propose to subtract 1 from MQ to compute TFP. However, for small TFP (in absolute terms), both methods yield almost identical results. Using logarithmic transformation is more similar to the Törnqvist index.

[8] The weights $\alpha_{n,t}$ in period t are given by the costs of input n in relation to total costs. As common in productivity analysis, we calculate weights as the mean of the current period t and the previous period $t-1$.

[9] For a more general discussion on measuring health care inputs and outputs, see Newhouse (1994), Bloor and Maynard (2006), Castelli *et al.* (2007), Hollingsworth (2008).

the number of discharges, a quality index, and the quality-adjusted number of discharges (outcome).[10] First, we use the annual number of in-patient discharges according to the strict separation of the in-patient hospital sector and the out-patient health care sector in Germany. The length of stay, in contrast, will be used here as an explanatory variable only in the second-stage regression.[11] Second, we construct a quality index which reflects mortality. According to Varabyova and Schreyögg (2013), successful treatments and quality improvements in hospital care materialize in decreases in hospital mortality. Our quality index increases from t to $t+1$ as the difference in growth rates of the in-patient mortality rate and the overall population mortality rate decreases. Subtracting overall population mortality accounts for health improvements that lie beyond hospital care (e.g., higher level of fitness, fewer smokers).[12] We use in-hospital mortality rates because the 30-days mortality rate as the preferable measure is not available. Data aggregation at the state level however absorbs idiosyncratic local events and re-admissions to a large extent. Third, we define hospital outcome (quality-adjusted discharges) as the product of the number of discharges and the mortality-based quality index.

Labor. We observe full-time equivalents of three types of labor input: physicians, nurses and other staff. The labor cost share is the ratio of total wages and total costs. Törnqvist labor growth is the sum of growth rates of each labor type, weighted by the two-year average wage share of each labor type (see Cromwell and Pope, 1989; O'Mahony and Timmer, 2009).

Capital. Fast-moving medical progress leads to an enormous increase in capital quality that is not captured by the number of hospital beds. We use self-compiled capital stocks for the hospital sector of all 16 states that reflect both capital quantity and quality. Our long-term investment series (1950–2013) for each of the 16 states base on a large set of data sources (see Section 4 and Table S.3 in the supplementary material).[13] We apply the Perpetual Inventory Method (PIM) (Schmalwasser and Schidlowski, 2006; OECD, 2009) and calculate capital stocks in constant prices as the sum of non-retired investments of

[10] For reasons of simplicity, we derive the quality index based TFP as the difference of outcome based TFP and output volume based TFP.
[11] We treat the length of stay as a main characteristic of a discharge but not as an output itself. Using the length of stay as an additional output does not allow to calculate TFP rates based on the Törnqvist index because explicit index weights of discharges and the length of stay are not derivable. Results of the second-stage regression however do not change to large extent when we use the length of stay as an additional output in the Malmquist framework and exclude the length of stay from the second-stage regression. For details, see the supplementary material (Table S.6).
[12] For example, if the in-hospital mortality rate decrease by 10% and the overall population mortality rate decrease by 7%, the hospital-related decrease in hospital mortality amounts to 10% – 7% = 3%. The quality index increases from 100.0 to (100.0 × 1.03) = 103.0.
[13] In Germany, no data on capital or investments of the hospital sector are collected, even at the national level.

prior periods. Further details are provided in the supplementary material. We compute the cost share of capital as the share of our estimated depreciation and interest payments.

Intermediate goods. Intermediate hospital goods such as food, medical goods, water, power or fuel supplies are essential to hospital production. We follow the KLEMS approach (O'Mahony and Timmer, 2009) and use separate series for energy (including water supply and the like), materials and service expenses in constant prices. We deflate energy expenses using the state-level consumer price index for energy and fuel.[14] Material expenses are deflated by the GDP price index, and services are deflated by the GDP-based price index for services. Cost shares for each type of intermediate goods are given by their two-year average cost shares.

3.3 Second-stage regression

We use the TFP growth rates derived in the first step as the dependent variable in a second-stage regression. We include time and state fixed effects. State fixed effects cover unobservable heterogeneity across German states (i.e., attitudes toward health and social care). Time effects eliminate effects of national reforms that affect all states simultaneously. We use growth rates of all variables to ensure stationarity, heteroskedasticity robust standard errors as proposed by Huber (1967) and White (1980), and mean 1993–2013 state population as regression weights.[15] Our OLS model takes the following form:

$$TFP_{i,t} = \alpha_i + \delta_t + P'_{i,t}\beta + Z'_{i,t}\gamma + \varepsilon_{i,t} \quad (3)$$

where $TFP_{i,t}$ represents the annual productivity change of state i in period t. α_i and δ_t define state and year fixed effects. $\varepsilon_{i,t}$ is the error term. P is a vector of the hospital policies shown in Figure 1; all variables are included in growth rates: the share of public hospitals and the share of private for-profit hospitals (private non-profit hospitals being the base category), the average hospital size in a federal state, a specialization measure (Gini index of beds in 18 state-aggregated hospital departments), the state budget share of hospital funding, and the number of students of human medicine. We also include a dummy for left-wing health ministers.[16] Finally, vector P includes hospital policy induced measures. These are the length of stay, the occupancy, and capital intensity (ratio of capital stock and total staff).

[14] If price indices for energy are not available at the state level, we instead apply the national counterpart. However, state-level and national price indices for energy only differ to small extent in Germany.
[15] Weighting accounts for substantial differences in state population. Inferences basically do not change when we use unweighted regressions.
[16] The dummy for left-wing health ministers equals one if the minister is affiliated with one of the left-wing parties SPD, Bündnis 90/Die Grünen or Die Linke, and zero otherwise.

We include a large set of further socio-demographic and political economy control variables, Z. These are the case mix index (Grosskopf *et al.*, 1993), which we proxy by the share of intensive care days,[17] patient flows between the states, and socio-demographic issues that may drive regional hospital demand (old-age dependency ratio, unemployment rate, GDP per capita). We also include the ratio of out-patient and in-patient physicians to capture substitutional (or complementary) effects between the hospital and the out-patient sector.

4. Data

Our dataset includes state-level aggregates of all variables for the period 1993 to 2013 for the 16 federal states (*Bundesländer*) of Germany. Data on output, and labor and intermediate inputs are obtained from the Federal Statistical Office of Germany. Main data sources for our self-compiled capital stocks are publications of the German hospital association on investment funding of general and specialized hospitals, and publications of the Federal Statistical Office documenting university hospitals' investments. We merge this data with a large number of studies on investments financed by hospitals' own funds, historical capital stocks and data on hospital funding in the former East German GDR.[18]

Figure 2 gives an impression of our dataset (Table S.2 in the supplementary material provides further descriptive statistics). The left-hand figure shows the evolution of the number of discharges, quality index, and outcome (quality-adjusted discharges) as well as the evolution of input volumes. Output volume, quality index, and outcome increase each year, the years 2004 to 2008 being the exception. The output volume roughly parallels the quality index. Growth rates of discharges and quality index of individual states are correlated by 0.59 between 1993 and 2013. Capital and intermediates follow the outcome trend. Labor virtually stagnates between 1993 and 2013. The cost shares of the three input types are shown in the right-hand part of Figure 2. All cost shares remain almost constant over the entire period of 20 years which corroborates findings for the US (Cylus and Dickensheets, 2008).

[Figure 2 about here]

[17] Data on the case mix index are not available for the period before 2004. However, the state-level case mix index and the share of intensive care days follow the same trend between 2005 and 2013. The correlation amounts to $r = 0.25$ and is significant at the 1% level. We also replaced the intensive care days by case mix index for the period from 2005 to 2013 as a robustness test. Inferences do not change (see Figure S.5 in the supplementary material).

[18] Table S.3 the supplementary material provides more details.

5. Results

5.1 TFP growth

Table I shows the mean growth rates of hospital TFP based on the number of discharges, on the quality index, and on outcome serving as output measure each (panel A). For sensitivity analyses, we also replace our input measures by conventionally used measures such as total staff, hospital beds, and total intermediates (panel B).[19]

[Table I about here]

We focus on outcome based productivity which reflects output quantity and quality and derive three main results. First, hospitals realize a substantial increase in outcome related TFP of 0.48% (Malmquist, column (5), third row) to 1.30% (Törnqvist, column (4)). The difference between Malmquist and Törnqvist TFP is mainly driven by the factor capital in East Germany. The exceptionally large growth rates in East German capital stocks in the 1990s shift the Malmquist index of East Germany and overall Germany downwards. In West Germany, Malmquist TFP (1.11%) equals Törnqvist TFP (1.09%) (for details see Table S.4 in the supplementary material). Given that the Törnqvist index is more reliable than the Malmquist index, TFP growth can be seen as the by far most important contribution to hospital outcome growth in Germany. Total input growth contributes 1.13% to outcome growth (sum of columns (1) to (3)). Figure 3 shows that TFP growth rates vary over time. Growth rates decrease monotonically until 2004. Since 2004, TFP growth re-increases. This turnaround corresponds with the introduction of the German Diagnosis-Related Group (DRG) system in 2004. We will discuss differences in subperiods in more detail later on.

[Figure 3 about here]

Second, gains in hospital TFP entirely stem from improvements in quality, which is in line with the results of Arocena and García-Prado (2007). Productivity growth in quality is larger than 0.8% per year in all specifications (see columns (4) and (5)). Output-input ratios of the number of discharges, by contrast, stagnate over time (-0.05%, see column (4)). Thus, TFP growth in German hospital care stems from quality improvements rather than from increases in output volumes.

[19] Only few studies have systematically compared the impact of different input-output specifications (e.g., Cromwell and Pope, 1989; Valdmanis, 1992).

Third, hospital TFP growth is a result of technological progress rather than efficiency induced. Technological progress (TECHCH, the shift of the frontier) contributes 0.32% to outcome based Malmquist TFP (column (7)); efficiency (EFFCH) contributes 0.16%. Thus, movements toward the technological frontier seem to play only a minor role for hospital TFP. Figure 3 underpins this finding. The evolution of Malmquist TECHCH (lower graphics, right-hand side) parallels the trend of TFP growth. By contrast, Malmquist EFFCH varies little over time and does not parallel TFP. We observe a similar evolution of the Törnqvist and the Malmquist index which are correlated by 0.80 for the entire period and all states.[20] This indicates that the neoclassical assumptions of the Törnqvist index seem to hold in the case of the German hospital sector, despite the very high level of state regulation.

At a first glance, hospital TFP in Germany seems to be a result of technologically induced improvements in quality. However, below we examine the sources of TFP growth in a second-stage regression in more detail and show below that also health care policies by state governments play an important role.

5.2 Effects of hospital policies

We link TFP growth rates to hospital policy in a second-stage regression. Table II shows our baseline results. Törnqvist TFP, Malmquist TFP, EFFCH and TECHCH are the dependent variables each. Due to their high correlations, all TFP measures yield similar results in many cases. Again, we mainly refer to outcome based productivity results (columns (9) to (12)).

[Table II about here]

We find significant effects of specialization and hospital size on Törnqvist TFP rates and on Malmquist subindices. Enlarging hospital size is positively and significantly correlated with the catch-up effect (EFFCH) in terms of quality (column (7) and (11)). At the same time, larger hospitals are also associated with less technological progress (TECHCH), see columns (4) and (12). This finding follows the conventional economic intuition of a trade-off between scale effects but less innovation when enlarging production. Both effects cancel out in the case of the Malmquist TFP corroborating micro-level evidence (e.g., Gaynor *et al.*, 2012). Productivity gains also accompany specialization. This is in line with economic intuition: Focusing on certain disciplines allows to produce to a higher quality and quantity. This effect is significant for the Törnqvist TFP (columns (1), (5), and (9)), and Malmquist EFFCH (columns (3) and (11)). Again, however, both effects cancel out for Malmquist TFP.

[20] In West Germany, the correlation amounts to 0.89.

Coefficients for other policy measures such as ownership, hospital funding, or training medical students do only occasionally turn out to be significant, but do not seem to have a systematic impact. The same holds true for our socio-economic control variables. Given that Törnqvist TFP is less biased by the large capital growth rates in East Germany in the 1990s and therefore more reliable than Malmquist TFP, our results indicate that hospital size and specialization are the main policy forces of hospital TFP growth. Governments can influence these variables directly via hospital capacity planning.

In almost all specifications, we also find a substantial and significant correlation between policy induced measures and productivity. In terms of outcome, a decrease of 1% in the average length of stay is associated with an increase of 0.9–1.2% in hospital productivity (columns (9) and (10)) which is in line with recent studies (Ashby *et al.*, 2000; Dimas *et al.*, 2012; Castelli *et al.*, 2015). The occupancy rate also turns out to be significant in several specifications, especially in the case of the number of discharges and outcome based productivity. Increasing hospital occupancy by 1% comes with an increase in productivity of about 0.3% (column (9) and (10)). We do not find effects of the capital intensity for the overall sample.

5.3 Large-scale reorganizations

The re-unification of Germany in 1990 allows us to examine the effects of hospital policies after large-scale reorganizations. After re-unification, the East German hospital sector was drastically reshaped and downscaled. Also enormous investments were made to modernize the outworn capital stock. East German state governments were able to design and to implement an efficiently scaled hospital sector overnight, which is in stark contrast to the more evolutionary slow-moving reforms in West Germany.

We elaborate on West and East Germany separately. The results in Table III show that the length of stay and the occupancy rate matter to outcome based TFP growth in both regions.[21] By contrast, we do not find any robust correlation of hospital policies and hospital TFP growth in East Germany.[22] The consolidation of the East German hospital sector in 1990 included closures and reorganizations of departments among all hospitals according to future needs. We conclude that gains from further reforms are low in the aftermath of large-scale hospital sector reorganizations.

[21] Results for discharges based and quality index based TFP are provided in the supplementary material. See Tables S.7 to S.10.

[22] Hospital size is the sole exception: An increase in East German hospital size comes with decreases in TFP. Interestingly, in West Germany, hospital size is positively correlated with TFP growth. Given that East German hospitals (323 beds on average) are substantially larger than West German hospitals (264 beds), we conclude that the turning point in the relation of hospital size and hospital TFP growth is between 260 to 320 beds per hospital.

In West Germany, by contrast, significant correlations of TFP growth and almost all policy variables imply that further health care reforms might be valuable source of productivity growth. However, political barriers may hinder consolidations. Productivity growth in West German hospitals is significantly lower under left-wing health ministers. Favoring a larger public sector, left-wing health ministers may impose less pressure on hospitals than right-wing health ministers. In East Germany, partisanship does not play a role which is consistent with the fact that the hospital sector is consolidated and there is less ideological conflict (Potrafke, 2013). We also find that increases in capital intensity comes with increases in hospital TFP in West Germany, where a general shortage in hospital capital is reported. In the modernized East German hospital sector, by contrast, increases in capital intensity do not stimulate TFP growth anymore. Thus, deepening capital may enhance hospital productivity as long as the hospital sector suffers from a shortage in capital.

5.4 Reimbursement schemes

We also exploit the nationwide change in hospital reimbursement from fixed daily (*per diem*) rates to activity-based financing (DRG) in 2004.[23] We interact all variables with a dummy variable for the DRG period (2004 to 2013) to study whether effects depend on different reimbursement schemes. In Table IV, we present the effects of hospital policies for the period of fixed daily (*per diem*) rates and for DRG reimbursement separately. In columns (9) to (12), we test whether differences between both periods are statistically different from zero. Corroborating all findings so far, the average length of stay is strongly negatively associated with TFP growth before and after 2004. Introducing DRG, however, almost tripled the coefficient; the difference of about 0.9 to 1.0 is significantly different from zero, at least at the 5% level (columns (9) and (10)). Under activity-based hospital financing, incentives to reduce the length of stay are much higher than under a fixed daily base rate (O'Reilly *et al.*, 2012).

The effect of other policies, by contrast, depend on the reimbursement scheme. Under fixed daily rates, increases in occupancy rates and hospital size are significantly correlated with TFP growth (see columns (1) to (3)). Larger and highly utilized hospitals allow for more treatment days which is in line with financial incentives from fixed daily reimbursement. By contrast, coefficients of specialization, privatization, and other policy measures do not turn out to be significant. This finding inverts under DRG funding: the occupancy rate and hospital size do not have a systematic effect on TFP growth (columns (5) to (8)). Instead, we find that DRG funding induces incentives to focus on discharges rather

[23] In 2003, hospitals can opt for DRG-based financing on a voluntary basis. Since 01.01.2004, DRG-based financing is mandatory for general hospitals in Germany.

than on treatment days in a profit maximization context. An increase of the share of private hospitals of 1% is associated with a significant increase in hospital productivity of 0.06%. Also specialization comes with gains in productivity (column (5) and (7)). Specialization leads to expertise which in turn materializes in a greater quantity and quality of discharges using a given input mix. Patient mobility provides further evidence for this channel. Under DRG funding, a larger share of patients moving to another state to receive hospitals treatments is significantly correlated with increases in TFP growth (see columns (5) and (6)). This indicates that the selection of patients into state hospital sectors according to the different specialization has increased. If specialized treatments are not provided by nearby hospitals in a certain state, patients might be better off to move to another state. DRG-induced reductions of the length of stay may also have deepened the links to the out-patient sector. We find a positive and significant correlation of TFP growth and the share of out-patient by in-patient physicians for the DRG period only (columns (5) and (6)). To sum up, the effects of hospital policies on productivity growth highly depend on the reimbursement scheme: Scale-related policies (hospital size, occupancy rates) matter under fixed daily rates funding; scope (specialization, privatization) drives TFP growth under DRG funding.

6. Conclusion

In this paper, we study policy determinants of hospital productivity growth in Germany. We find that quality improvements rather than increases in quantity volumes generate TFP growth in hospital care. In any case, reducing the length of stay is a proper way to enhance hospital TFP. The effects of other hospital policies depend on the reimbursement scheme: scope-related policies (privatization, specialization) come with TFP growth under activity-based hospital funding. Under fixed daily rate reimbursement, scale (hospital size, occupancy rates) matters to TFP growth. These results imply that hospital reform measures should always be in line with reimbursement incentives. The case of East Germany also shows that large-scale reforms can be a perfect equivalent for incremental changes. After drastic consolidations of the hospital sector, there is less scope for further effects of hospital policy.

Our study derives insights from the frontier Malmquist approach and from the non-frontier Törnqvist approach. We also show that TFP calculations are more sensitive to different measures of inputs and outputs rather than to different index concepts. Malmquist and the Törnqvist TFP are correlated by 0.80 for the entire period and for all states. We conclude that the strictly neoclassical assumptions of the Törnqvist index hold despite the very high level of state regulation of the hospital sector. By contrast, using hospital beds as capital input may bias productivity rates upwards because the number of beds does not reflect capital quality.

Limitations of this study may encourage further research. First, our input measures capture quality as best as possible whereas output quality was proxied by in-hospital mortality. Further studies on hospital TFP may elaborate on more precise output measures. Second, studies on hospital TFP should use more precise measures and test different methods in measuring TFP for robustness exercises. The well-developed survey of Del Gatto *et al.*, (2011) outlines a global picture of TFP methodology that has not been systematically discussed with respect to health care issues.

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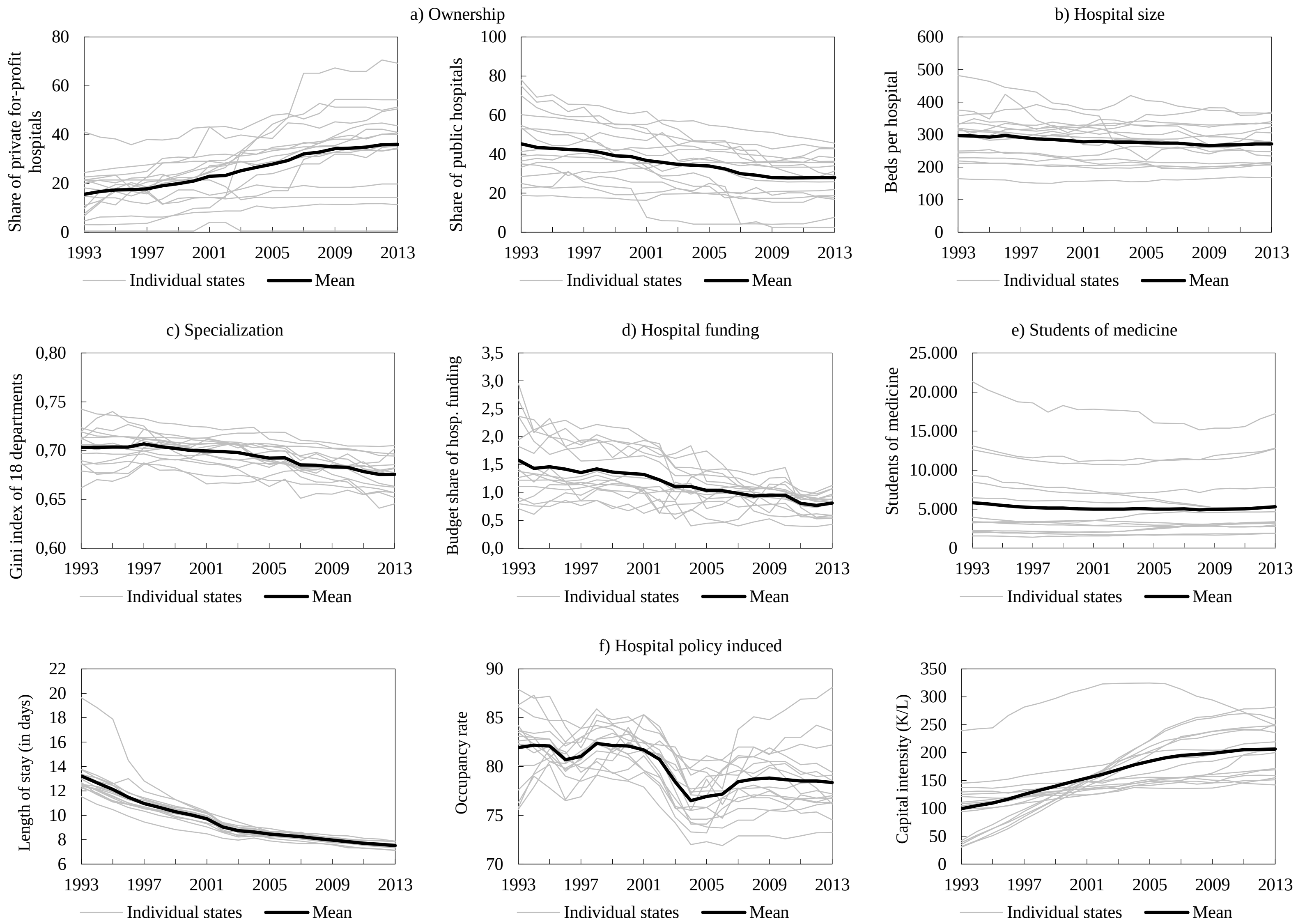
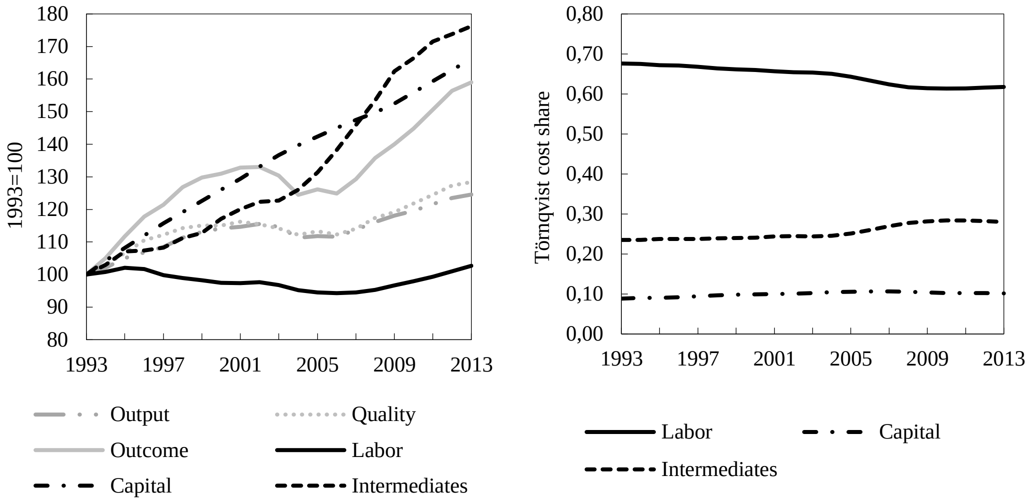
FIGURE 1. STATE VARIATION IN GERMAN HOSPITAL POLICY



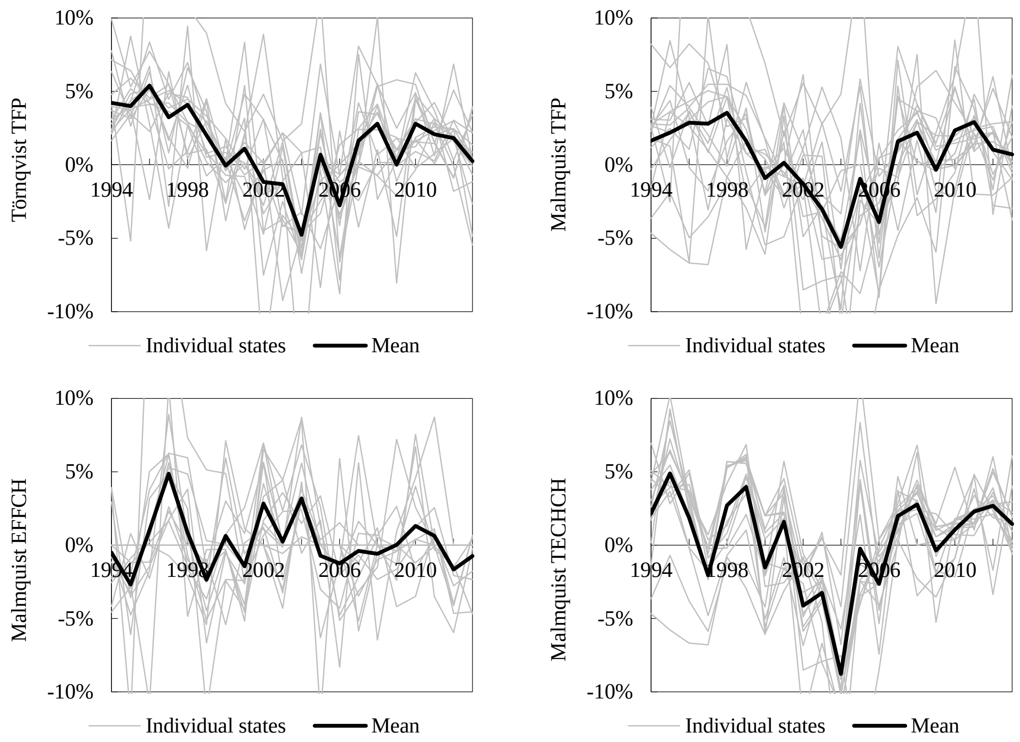
Notes: Figures show different hospital policies or policy induced strategies of the 16 German states for the period from 1993 to 2013. Gray lines show individual states, the dark bold line represents the state average.

FIGURE 2. OUTPUTS AND INPUTS, TÖRNQVIST COST SHARES



Notes: The figures shows the evolution of hospital output and inputs (national aggregates) in Germany, 1993–2013, and the evolution of the Törnqvist cost shares, which add up to one.

FIGURE 3. HOSPITAL TFP GROWTH IN GERMANY, 1993–2013



Notes: The figure depicts the evolution Törnqvist and Malmquist hospital TFP growth, 1993–2013. Gray lines show individual states, the dark bold line represents the state average.

TABLE I. PRODUCTIVITY RESULTS, 1993–2013

Output variable	*Törnqvist*				*Malmquist*		
	Input growth contributions[a]			*TFP*	*TFP*	*Thereof:*	
	Labor	*Capital*	*Intermediate goods*			*EFFCH*	*TECHCH*
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Panel A: Baseline (Labor: 3 types of staff, Capital: Capital stocks, Intermediates: 3 types of intermediates)							
Number of discharges	0.01%	0.34%	0.78%	-0.05%	-0.37%	0.30%	-0.67%
Quality index	0.01%	0.34%	0.78%	1.35%	0.85%	-0.14%	0.99%
Outcome	0.01%	0.34%	0.78%	1.30%	0.48%	0.16%	0.32%
Panel B: Sensitivity test (Labor: total staff, Capital: beds, Intermediates: total intermediates)							
Number of discharges	-0.18%	-0.12%	0.80%	0.59%	1.01%	0.32%	0.69%
Quality index	-0.18%	-0.12%	0.80%	1.35%	1.34%	-0.26%	1.60%
Outcome	-0.18%	-0.12%	0.80%	1.94%	2.35%	0.06%	2.29%

Notes: The table depicts the results of our TFP calculations. a) The sum of the growth contributions of all inputs and TFP is identical to the output growth rate.

TABLE II. SECOND-STAGE REGRESSION, 1993–2013

	Number of discharges				*Quality index*				*Outcome (quality-adjusted discharges)*			
	Törnqvist	*Malmquist*			*Törnqvist*	*Malmquist*			*Törnqvist*	*Malmquist*		
	TFP	*TFP*	*EFFCH*	*TECHCH*	*TFP*	*TFP*	*EFFCH*	*TECHCH*	*TFP*	*TFP*	*EFFCH*	*TECHCH*
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Policy												
Δln *Share of public hospitals*	-0.002	0.001	0.002	-0.001	0.005	0.003	0.001	0.002	0.003	0.004	0.002	0.001
Δln *Share of private for-profit hospitals*	0.002	-0.008	-0.008	-0.000	0.006	0.005	0.016	-0.011	0.008	-0.003	0.008	-0.011
Δln *Hospital size*	0.071*	-0.015	0.050	-0.065*	0.073	0.078	0.129***	-0.050	0.144**	0.063	0.178***	-0.115**
Δln *Specialization*	0.228**	0.100	0.260***	-0.160	0.224*	-0.039	0.229	-0.268**	0.452**	0.062	0.489**	-0.427**
Δln *Share of hospital funding*	0.006	0.007	0.014**	-0.007	-0.009	-0.004	-0.013*	0.009*	-0.004	0.003	0.001	0.001
Δln *Students of human medicine*	0.012	0.015	0.041	-0.026	0.021	0.004	0.011	-0.007	0.033	0.019	0.052	-0.033
Left-wing health minister	0.001	0.004	0.004*	-0.000	-0.008***	-0.010***	-0.009**	-0.001	-0.006	-0.006	-0.005	-0.001
Hospital policy induced												
Δln *Length of stay*	-0.400***	-0.607***	-0.541***	-0.067	-0.488***	-0.571***	-0.236	-0.335**	-0.888***	-1.179***	-0.777***	-0.402**
Δln *Occupancy rate*	0.176***	0.143	0.177***	-0.034	0.160	0.168	0.140	0.028	0.336**	0.311*	0.317**	-0.006
Δln *Capital intensity*	0.018	0.032	0.011	0.021	-0.035	-0.219***	-0.081*	-0.138***	-0.017	-0.187**	-0.070	-0.117*
Socio-economic conditions												
Δln *Share of intensive care days*	-0.057	-0.033	0.003	-0.036*	-0.062	-0.073	-0.025	-0.048	-0.119*	-0.107	-0.022	-0.084*
Δln *Share of in-commut. patients from other s.*	-0.000	0.006	0.010	-0.004	-0.002	0.001	0.021	-0.019	-0.002	0.007	0.031	-0.023
Δln *Share of out-commut. patients to other s.*	-0.008	0.008	-0.013	0.021	0.028	0.042	-0.001	0.043	0.020	0.050	-0.014	0.064**
Δln *Out-patient physician per in-patient phys.*	0.051**	0.112***	0.009	0.103*	0.061	0.076	-0.078	0.154*	0.112	0.188**	-0.069	0.257**
Δln *Old-age dependency ratio*	0.381*	0.209	0.434*	-0.226	0.248*	0.236	-0.136	0.372**	0.629*	0.445	0.298	0.147
Δln *Unemployment rate*	-0.028	-0.026	-0.019	-0.007	0.009	0.013	0.053	-0.040	-0.019	-0.013	0.034	-0.046
Δln *GDP per capita*	-0.169**	-0.267**	-0.106	-0.162	0.057	0.146	0.014	0.132	-0.112	-0.121	-0.092	-0.029
Constant	-0.002	-0.024*	-0.020**	-0.004	0.022**	0.021	-0.004	0.025***	0.020	-0.003	-0.024	0.021
Obs.	320	320	320	320	320	320	320	320	320	320	320	320
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared (within)	0.602	0.480	0.336	0.582	0.600	0.530	0.465	0.736	0.637	0.580	0.534	0.749

Notes: The table shows the results of second-stage regressions using output, quality and outcome based TFP calculations as the dependent variable (columns (1)–(4): output, columns (5)–(8): quality, columns (9)–(12): outcome). The unit of observation are the 16 German states. All variables in growth rates (with exceptions of the dummy variables). Average state population 1993–2013 serves as regression weight. Significance levels (robust standard errors): *** 0.01, ** 0.05, * 0.10.

TABLE III. WEST GERMANY AND EAST GERMANY, 1993–2013

	Outcome (quality-adjusted discharges)							
	West Germany[a]				*East Germany*[b]			
	Törnqvist	*Malmquist*			*Törnqvist*	*Malmquist*		
	TFP	*TFP*	*EFFCH*	*TECHCH*	*TFP*	*TFP*	*EFFCH*	*TECHCH*
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Policy								
Δln *Share of public hospitals*	0.005	0.008	0.002	0.006	0.033	0.011	-0.002	0.013
Δln *Share of private for-profit hospitals*	0.026	0.010	0.011	-0.001	0.016	-0.006	0.010	-0.016
Δln *Hospital size*	0.200**	0.117	0.205**	-0.087	0.051	-0.216**	-0.019	-0.197**
Δln *Specialization*	0.782***	0.534**	0.970***	-0.436	0.003	-0.982	-0.070	-0.911
Δln *Share of hospital funding*	0.003	0.012	0.007	0.005	-0.019*	-0.029	-0.012	-0.018
Δln *Students of human medicine*	0.051	0.082	0.128	-0.046	0.227	0.127	0.137	-0.010
Left-wing health minister	-0.011**	-0.011*	-0.010**	-0.001	0.003	0.003	0.002	0.001
Hospital policy induced								
Δln *Length of stay*	-0.721**	-1.054***	-0.726***	-0.328*	-1.355**	-1.215	-0.803*	-0.411
Δln *Occupancy rate*	0.339*	0.351	0.366*	-0.015	0.549**	0.674*	0.330	0.345**
Δln *Capital intensity*	0.263**	0.187*	0.157	0.030	-0.018	-0.246	-0.240*	-0.005
Socio-economic conditions								
Δln *Share of intensive care days*	-0.201*	-0.183*	-0.090	-0.094	-0.018	-0.029	0.037	-0.066
Δln *Share of in-commut. patients from other states*	0.032	0.046	0.059	-0.013	-0.014	-0.007	0.014	-0.021
Δln *Share of out-commut. patients to other states*	0.050	0.043	-0.033	0.075**	0.003	0.244***	0.115	0.129
Δln *Out-patient physician per in-patient physician*	0.021	0.133	-0.171	0.304***	-0.052	-0.218	-0.282**	0.064
Δln *Old-age dependency ratio*	0.821*	0.905	0.799*	0.106	-0.158	-0.883	-0.660	-0.223
Δln *Unemployment rate*	-0.028	-0.043	0.013	-0.056*	0.056	0.304	-0.013	0.316*
Δln *GDP per capita*	-0.057	-0.066	-0.075	0.009	-0.227	-0.376	-0.414*	0.038
Constant	0.013	0.010	-0.002	0.011	0.000	0.062	0.030	0.032
Obs.	220	220	220	220	100	100	100	100
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared (within)	0.669	0.661	0.601	0.800	0.760	0.610	0.610	0.690

Notes: The table shows the results of second-stage regressions by subsamples (11 West German states, 5 East German states) using outcome based TFP calculations as the dependent variable. All variables in growth rates (with exceptions of the dummy variables). Average state population 1993–2013 serves as regression weight. a) Including East Berlin. b) Excluding East Berlin. Significance levels (robust standard errors): *** 0.01, ** 0.05, * 0.10.

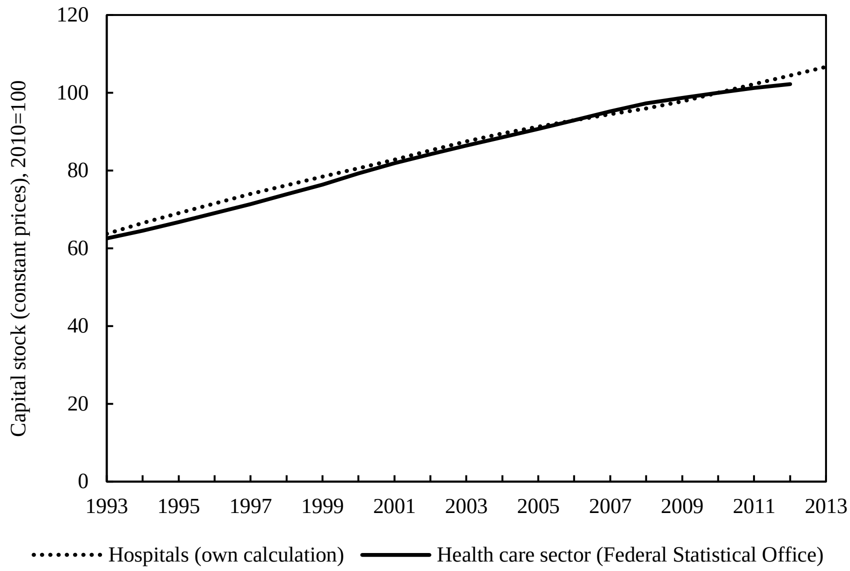
TABLE IV. DIFFERENT REIMBURSEMENT SCHEMES

	Outcome (quality-adjusted discharges)											
	Reimbursement scheme								*Difference*			
	Fixed daily rates (1993–2003)				*DRG (2004–2013)*							
	Törnqvist	*Malmquist*			*Törnqvist*	*Malmquist*			*Törnqvist*	*Malmquist*		
	TFP	*TFP*	*EFFCH*	*TECHCH*	*TFP*	*TFP*	*EFFCH*	*TECHCH*	*TFP*	*TFP*	*EFFCH*	*TECHCH*
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Policy												
Δln *Share of public hospitals*	0.021	0.019	0.036*	-0.017	-0.009	-0.006	-0.025	0.019	-0.030	-0.025	-0.061**	0.036
Δln *Share of private for-profit hospitals*	0.004	-0.006	0.031	-0.038**	0.059*	0.057**	-0.025	0.082***	0.055	0.063**	-0.057**	0.120***
Δln *Hospital size*	0.130*	0.069	0.225**	-0.157***	0.116	0.000	0.108*	-0.108	-0.015	-0.068	-0.117	0.049
Δln *Specialization*	0.450	0.274	0.448	-0.174	0.776**	0.289	0.792*	-0.504*	0.326	0.015	0.345	-0.329
Δln *Share of hospital funding*	-0.013	-0.013	-0.000	-0.012	-0.002	0.006	-0.002	0.008	0.010	0.019	-0.002	0.020
Δln *Students of human medicine*	0.047	0.103	0.147	-0.044	-0.009	-0.069	-0.000	-0.068	-0.056	-0.171	-0.147	-0.024
Left-wing health minister	-0.008*	-0.005	-0.008	0.004	-0.003	-0.007	-0.001	-0.006	0.005	-0.003	0.007	-0.010
Hospital policy induced												
Δln *Length of stay*	-0.637**	-0.967***	-0.646**	-0.320***	-1.677***	-1.886***	-1.312***	-0.574*	-1.040***	-0.920**	-0.666	-0.254
Δln *Occupancy rate*	0.474**	0.555*	0.649**	-0.094	0.194	0.046	-0.001	0.046	-0.280	-0.509	-0.650**	0.141
Δln *Capital intensity*	0.027	-0.203*	-0.066	-0.138*	0.092	-0.120	-0.108	-0.012	0.065	0.083	-0.042	0.125
Socio-economic conditions												
Δln *Share of intensive care days*	-0.099	-0.069	-0.010	-0.060	-0.067	-0.108	0.008	-0.116	0.032	-0.039	0.018	-0.056
Δln *Share of in-commut. patients from other states*	0.006	0.015	0.020	-0.006	0.015	0.016	0.036	-0.020	0.009	0.001	0.016	-0.015
Δln *Share of out-commut. patients to other states*	-0.043	0.002	0.033	-0.031	0.089*	0.098**	-0.032	0.130***	0.133	0.096	-0.065	0.160**
Δln *Out-patient physician per in-patient physician*	0.006	0.135	-0.152	0.287**	0.239**	0.259**	-0.030	0.290**	0.233*	0.124	0.121	0.003
Δln *Old-age dependency ratio*	0.712	0.482	0.438	0.044	0.595**	0.328	0.138	0.190	-0.116	-0.154	-0.300	0.146
Δln *Unemployment rate*	0.035	0.050	0.103	-0.053	-0.051	-0.040	-0.015	-0.025	-0.086	-0.090	-0.118	0.028
Δln *GDP per capita*	-0.221	-0.105	-0.216	0.111	-0.019	-0.153	-0.059	-0.094	0.201	-0.048	0.157	-0.205
Obs.	–	–	–	–	–	–	–	–	320	320	320	320
Time fixed effects	–	–	–	–	–	–	–	–	Yes	Yes	Yes	Yes
State fixed effects	–	–	–	–	–	–	–	–	Yes	Yes	Yes	Yes
R-squared (within)	–	–	–	–	–	–	–	–	0.700	0.634	0.590	0.776

Notes: The table shows the results of second-stage regressions by subperiods using outcome based TFP calculations as the dependent variable. Results come from a model using the interaction of policy measures and a dummy which equals one for activity-based hospital funding (2003–2013), and zero otherwise. Columns (1)–(4) show the effects for the period prior the introduction of activity-based hospital funding (DRG) (1993–2003), Columns (5)–(8) show the effects for the period afterwards. Columns (9) to (12) takes the differences between both periods. Coefficients for the constant and the interaction dummies are left out. All variables in growth rates (with exceptions of the dummy variables). Average state population 1993–2013 serves as regression weight. Significance levels (robust standard errors): *** 0.01, ** 0.05, * 0.10.

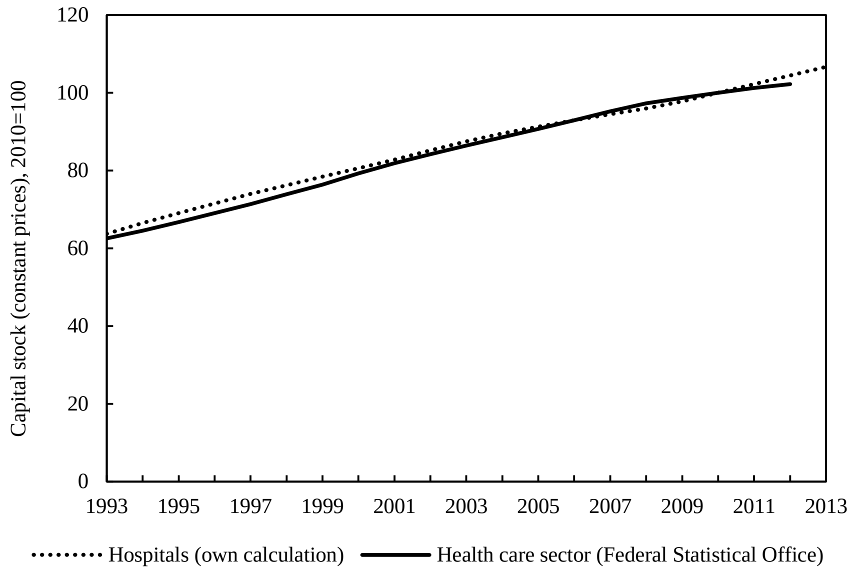
Supplementary material (for online publication only)

FIGURE S.1. PLAUSIBILITY CHECK FOR CAPITAL STOCK CALCULATIONS I



Notes: The figure shows the evolution of our calculated hospital capital stock (national aggregation) (dotted line) and the capital stock of the overall health care sector (solid line) as provided by Federal Statistical Office (2015), Volkswirtschaftliche Gesamtrechnungen, Inlandsproduktsberechnung, Detaillierte Jahresergebnisse, 2014 (and previous volumes), Fachserie 18, Reihe 1.4, published 09.03.2015. Both series show the capital stock in real terms and are indexed to 100 in 2010. The similar evolution of both series gives support to our calculations, as the hospital sector accounts for a large part of the overall health care sector.

FIGURE S.2. PLAUSIBILITY CHECK FOR CAPITAL STOCK CALCULATIONS II



Notes: The figure shows the evolution of our calculated hospital capital stock (national aggregation) as a share of the capital stock of the overall health care sector (solid line) as provided by Federal Statistical Office (2015), Volkswirtschaftliche Gesamtrechnungen, Inlandsproduktsberechnung, Detaillierte Jahresergebnisse, 2014 (and previous volumes), Fachserie 18, Reihe 1.4, published 09.03.2015. Furthermore, the figure gives the share of hospital sector current expenditures of total in- and out-patient care sectors' expenditures (dotted line); source: Federal Statistical Office (2014), Gesundheit, Ausgaben, 2012 (and previous volumes), Fachserie 18, Reihe 1.4, published 07.04.2014). The figure depicts that the share of the hospital sector in terms of capital is only slightly above the share of the hospital sector in current expenditures, which gives support to our capital stock calculations.

TABLE S.1. RECENT STUDIES CALCULATING HOSPITAL TFP (DETERMINISTIC METHODS ONLY)

	Country and period	Level	TFP finding (annualized)	Output[h]					Input								
				Monetary	Non-monetary				Labor					Capital			Interm.
				Production value/Revenue	Dis-charges	Days	Procedures	Others	Total staff	Physicians	Nursery staff	Other staff	Expenses	Capital stock	Beds	Expenses	Expenses
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
Malmquist index (DEA)[a]																	
Afonso and Fernandes (2008)	PT (2000–2005)	Hospital	-8.3 to 10.9%		×	×	×			×	×	×	×		×		
Barros et al. (2008)	PT (1997–2004)	Hospital	3.6%		×		×	Length of stay	×[b]						×		×[e]
Gannon (2008)	IE (1995–1998)	Hospital	-0.3 to 2.8%		×	×				×[b]	×[b]	×[b]			×		
Chowdhury et al. (2010)	US (2003–2006)	Hospital	-0.7%		×	×				×[b]	×[b]				×		×
de Castro Lobo et al. (2010)	BR (2003–2006)	Hospital	6.9%						×[b]	×					×		×[e]
Tlotlego et al. (2010)	BW (2006–2008)	Hospital	-1.5%		×	×			×						×		
Chang et al. (2011)	TW (1998–2004)	Hospital	2.1%		×	×		Mortality		×	×	×			×		
Huerta et al. (2011)	US (2002–2006)	Hospital	0.6%		×	×	×	Case mix					×		×		×[e]
Ng (2011)	CN (2004–2008)	Hospital	7.4 to 38.7%		×					×	×	×			×		
Nghiem et al. (2011)	AU (1996–2004)	Hospital	1.2 to 1.6%		×					×[b]	×[b]	×[b]			×		
Pham (2011)	VN (1998–2006)	Hospital	1.4%		×	×	×		×[b]						×		
Roh et al. (2011)	US (1993–2003)	Hospital	1.1%	×	×				×[b]						×		×[e]
Sulku (2011)	TR (2001–2006)	Hospital	6.4%		×	×	×	Quality	×	×					×		
Dimas et al. (2012)	GR (2003–2005)	Hospital	-5.0 to 2.0%		×	×							×		×		×[e]
Karagiannis and Velentzas (2012)	GR (2002–2007)	Hospital	-1.2 to 1.4%		×				×	×					×		
Thompson et al. (2012)	US (2005–2008)	Hospital	-1.4%		×	×		Case mix					×		×		
De Nicola et al. (2013)	IT (1999–2008)	Region	-8.2%		×			Quality, case mix		×	×				×		
Huerta et al. (2013)	US (2005–2008)	Hospital	0.8%		×	×	×		×[b]		×[b]				×		
Roh et al. (2013)	US (2002–2006)	Hospital	-0.9%	×[g]	×	×	×	Charity care	×[b]					×[f]	×		
Bwana (2014)	TZ (2001–2012)	Hospital	-1.6%		×	×	×		×[b]						×		
Li et al. (2014)	CN (2006–2009)	Hospital	26.7%		×	×			×						×		
Torabipour et al. (2014)	IR (2007–2010)	Hospital	2.4%		×		×	Length of stay		×	×				×		
Castelli et al. (2015)	UK (2008–2010)	Hospital	0.4%		×		×	Survival r., life expect.	×							×	×[e]
Törnqvist index																	
Cromwell and Pope (1989)	US (1981–1986)	National	-4.1 to -0.2%	×	×	×				×	×	×		×[c]			
Cylus and Dickensheets (2008)	US (1981–2005)	National	0.0 to 0.4%	×					×				×	×[c]		×	×
Harper et al. (2010)	US (1987–2006)	National	-0.9%	×					×[b]							×[d]	×
Gu and Morin (2014)	CA (2002–2008)	National	0.3%					Output in-dex	×[b]					×			×

Notes: ×: Study applies measure. a) Studies after 2008 only. For a review of prior studies, see Hollingsworth (2008). b) Full-time equivalents. c) Fixed Assets. d) Capital services. e) Total variable costs. f) Current assets only. g) Profits only. h) In-patient and/or out-patient

TABLE S.2. DESCRIPTIVES

		Obs.	*Mean*	*Min.*	*Max.*	*Std. Der.*	*Average growth rate*
		(1)	(2)	(3)	(4)	(5)	(6)
Output	*Number of discharges*	336	1,045,733	164,499	4,407,169	980,955	1.08%
	Quality index	336	120	95	172	13	1.35%
	Outcome (quality-adjusted discharges)	336	1,241,888	173,603	5,996,737	1,168,073	2.44%
Inputs	*Physicians (full-time equivalents)*	336	7,373	1,205	33,809	6,854	2.08%
	Nursing staff (full-time equivalents)	336	20,120	3,465	82,726	18,497	-0.24%
	Other staff (full-time equivalents)	336	24,663	3,334	96,986	22,614	-0.98%
	Capital stock (in 1.000 Euro[a])	336	8,300,107	588,935	33,100,000	7,441,295	4.13%
	Energy (in 1.000 Euro[a])	336	66,843	8,773	315,155	64,483	1.26%
	Materials (in 1.000 Euro[a])	336	993,301	137,100	4,780,383	961,358	3.05%
	Services (in 1.000 Euro[a])	336	60,069	6,511	388,777	68,711	3.99%
Törnqvist cost shares	*Labor*	320	0.65	0.52	0.74	0.04	–
	Physicians (share of total labor)	320	0.25	0.19	0.34	0.04	–
	Nursing staff (share of total labor)	320	0.35	0.28	0.42	0.03	–
	Other staff (share of total labor)	320	0.40	0.32	0.48	0.02	–
	Capital	320	0.10	0.03	0.18	0.03	–
	Intermediate goods	320	0.26	0.22	0.37	0.03	–
	Energy (share of total intermediates)	320	0.07	0.05	0.11	0.01	–
	Materials (share of total intermediates)	320	0.88	0.79	0.91	0.02	–
	Services (share of total intermediates)	320	0.05	0.03	0.16	0.02	–
Inputs for sensitivity analysis	*Total staff (full-time equivalents)*	336	52,156	8,315	202,004	47,713	-0.27%
	Beds	336	34,092	5,111	153,897	32,657	-1.23%
	Total intermediate goods (in 1.000 Euro[a])	336	1,130,108	135,553	5,458,887	1,078,933	3.05%
Second-stage regression variables	Policy						
	Share of public hospitals	336	0.35	0.02	0.78	0.15	-2.88%
	Share of private for-profit hospitals	336	0.26	0	0.71	0.15	4.43%
	Hospital size	336	280	151	482	67	-0.42%
	Specialization	336	0.69	0.64	0.74	0.02	-0.20%
	Share of hospital funding	336	0.02	0.00	0.04	0.01	-1.74%
	Students of human medicine	336	5,156	0	21,336	4,707	-0.10%
	Left-wing health minister	336	0.58	0.00	1.00	0.49	–
	Hospital management						
	Length of stay	336	9.50	7.11	19.63	1.88	-2.79%
	Occupancy rate	336	0.80	0.72	0.88	0.03	-0.22%
	Capital intensity (capital stock/total staff)	336	162.86	30.33	324.64	58.91	4.39%
	Socio-economic conditions						
	Share of intensive care days	336	0.05	0.02	0.09	0.01	3.29%
	Share of in-com. patients from other states	336	0.10	0.03	0.37	0.08	0.65%
	Share of out-com. patients to other states	336	0.09	0.03	0.19	0.04	0.79%
	Out-patient physician per in-patient phys.	336	0.88	0.67	1.09	0.09	-0.66%
	Old-age dependency ratio	336	0.30	0.19	0.41	0.05	1.91%
	Unemployment rate	336	0.12	0.04	0.22	0.05	-1.11%
	GDP per capita (in 1.000 Euro[a])	336	28.78	13.72	55.11	8.53	1.46%

Notes: The table depicts the descriptives of our overall dataset (16 states, 21 years). a) 2013 constant prices.

TABLE S.3. DATA COMPUTATION AND SOURCES

Variable	*Computation*	*Sources*
Output	The outcome y_t in period t has been calculated as the number of in-patient discharges (*Entlassungen aus vollstationärer Behandlung*) which is the output volume d_t, weighted by a quality index q_t. Hence, $y_t = q_t d_t$. The quality index q_t is given by the product of a hospital mortality index and an inverse overall population mortality index: $q_t = \left[\left(\frac{d_{m,t}}{d_t}\right)\left(\frac{d_{m,1}}{d_1}\right)^{-1}\right]\left[\left(\frac{p_{m,t}}{p_t}\right)^{-1}\left(\frac{p_{m,1}}{p_1}\right)\right]$ where d_t gives the number of discharges in t, and d_1 is the number of discharges in the initial period. d_m defines the number of mortality cases. Similarly, p_t gives the overall population in a state, $p_{m,t}$ the number of deaths in this state in t.	Federal Statistical Office (2014a), Gesundheit. Grunddaten der Krankenhäuser, 2013 (and previous volumes). Fachserie 12, Reihe 6.1.1, published on 26.09.2014, Wiesbaden.
Labor	Labor volume is represented by full-time equivalents of physicians, nurses and other staff (*Personal (umgerechnet in Vollkräfte): Hauptamtliche Ärzte und Ärztinnen, Pflegedienst, Sonstiges Personal*)	Federal Statistical Office (2014a), Gesundheit. Grunddaten der Krankenhäuser, 2013 (and previous volumes). Fachserie 12, Reihe 6.1.1, published on 26.09.2014, Wiesbaden.
Capital	For measuring capital, we use a simplified version of the Perpetual Inventory Method. Basically, we calculate the capital stock K_t as the sum of the survived investments of all prior periods $\tau < t$. Thus, K_t is given by $K_t = \sum_{\tau=1}^{t-1} I_\tau \cdot (1 - F(\tau))$. Based on a study of German hospitals, we assume an average service life of 20 years of the overall "hospital capital good mix". This assumption relies on a study on German hospitals that reveals a linear depreciation rate of approximately 5% (Berliner Krankenhausgesellschaft and Senatsverwaltung für Gesundheit, Umwelt und Verbraucherschutz, 2011). We define: $F(\tau) = \begin{cases} \int f(\tau) \\ 0 \; if \; \int f(\tau) < 0.01 \end{cases}$ with: $f(t) = 9^9 (8!)^{-1} 20^{-9} t^8 e^{(-\frac{9t}{20})}$. The second term $f(t)$ gives the mortality function of capital goods of an average life of 20 years (Schmalwasser and Schidlowski, 2006). The integral of the mortality function yields the share of retired goods of a cohort. We define a break condition if the share of survived goods falls below 1%. We compute long-term investment series (1950–2013) for all states. Total investment consists of the following four sources: regular public investment (*KHG-Mittel*), investment of university hospitals (*Investitionen der Hochschulkliniken*), other public investments (*Sonstiges*) and own funds (*Eigenmittel*). For all states, we observe *KHG-Mittel* and *Investitionen der Hochschulkliniken* after 1991 (Deutsche Krankenhausgesellschaft 2014, Federal Statistical Office 2014b). For investments before 1991, we have to make several assumptions, especially concerning state-level investments before 1972 for West Germany and before 1991 for the six less-documented states of the former GDR. Our estimates are based on official governmental documents (BT-Drs. V/4230) and historical documentation (Arnold und Schirmer, 1990; Institut für angewandte Wirtschaftsforschung, 1990; Schwarzer, 1999; Bruckenberger, 2002; Bruckenberger, 2006). From these sources, we calculate a public financed capital stock. In addition, we assume own funded investments to be zero up to 1991 following Augursky (2013). Afterwards, we assume a rising level of own-funded capital stock leading to the level of the own-funded capital stock measured by Augursky (2013).	Berliner Krankenhausgesellschaft and Senatsverwaltung für Gesundheit, Umwelt und Verbraucherschutz (2011), Investitionsbedarf der Krankenhäuser in Berlin, Berlin. Schmalwasser O. and M. Schidlowski (2006), Measuring Capital Stock in Germany. Slightly abridged [English] version of a paper published in *Wirtschaft und Statistik* 11: 1–15. Deutsche Krankenhausgesellschaft (2014): Bestandsaufnahme zur Krankenhausplanung und Investitionsfinanzierung in den Bundesländern, Stand: Januar 2013, Berlin. Federal Statistical Office (2014b), Bildung und Kultur. Finanzen der Hochschulen, 2012 (and previous volumes, provided on request). Fachserie 11, Reihe 4.5, published on 12.06.2014, Wiesbaden. BT-Drs. V/4230. Arnold, M. and B. Schirmer (1990), Gesundheit für ein Deutschland, Deutscher Ärzte-Verlag, Köln. Institut für angewandte Wirtschaftsforschung (1990), Wirtschaftsreport: Daten und Zahlen zur wirtschaftlichen Lage Ostdeutschlands, Verlag Die Wirtschaft Berlin, Berlin. Schwarzer, O. (1999), Sozialistische Zentralplanwirtschaft in der SBZ/DDR. Ergebnisse eines ordnungspolitischen Experiments (1945-1989). *Vierteljahrschrift für Sozial- und Wirtschaftsgeschichte* Beiheft 143. Bruckenberger, E. (2002), Investitionsoffensive für Krankenhäuser?, Hannover. Bruckenberger, E. (2006), Angebots-, Nachfrage- und Finanzierungsstrukturen. In: Bruckenberger, E., Klaue, S. and H.-P. Schwintowski (Eds.), Krankenhausmärkte zwischen Regulierung und Wettbewerb, Springer, Berlin, Heidelberg: 29–84. Augursky, B. (2013), Krankenhaus Rating Report 2013: Können wir uns die aktuelle Krankenhauslandschaft noch leisten? Presentation at the Interaktiver Workshop der Finanzierungskommission der DGGG, 06.12.2013.
Intermediate goods	Intermediate goods volumes are separately calculated for energy, material and services. The volume for energy is given by the costs for water, energy and supply (*Wasser, Energie, Brennstoffe*) deflated by the consumer price index for housing, water, electricity, gas and other fuels. If available, a state-level consumer price index has been applied. Otherwise, the federal index has been used. The volume for services is calculated as the sum of the costs for central management services and service centers, taxes, duties, insurance (*Zentrale Verwaltungsdienste, Zentrale Gemeinschaftsdienste, Steuern, Abgaben, Versicherungen*), deflated with a GDP-	Federal Statistical Office (2014c): Gesundheit. Kostennachweis der Krankenhäuser, 2013 (and previous volumes), Fachserie 12, Reihe 6.3, published on 11.11.2014, Wiesbaden.

	based state-level price index for services. The volume for material consists of the residual costs not covered by energy or services, deflated by the state-level GDP price index. Due to a conceptual change from gross to net costs in 1996 and the reverse in 2002, in these years, changes in costs are given by the change in overall adjusted costs (*Bereinigte Kosten*).	
Törnqvist cost shares	The labor cost shares of the Törnqvist index is calculated as the share of total wages, deflated by the GDP price index, of overall costs. Capital costs are given by depreciation (proxied by 5% of the annual capital stock in real terms, see above) plus interest rate payments (*Zinsaufwendungen*), deflated by the GDP price index. Division by overall costs gives the capital cost share. Cost share of intermediate goods are given as the sum of intermediate goods by overall costs. Overall costs consist of the sum of labor, capital and intermediate goods costs. Note that the shares enter the Törnqvist index as two-year means. The shares for the Törnqvist sub-indices for labor (weights: share of wages of each labor type) and intermediates (weights: cost shares) are derived likewise. Due to a conceptual change from gross to net costs in 1996 and the reverse in 2002, in these years, changes in costs are given by the change in overall adjusted costs (*Bereinigte Kosten*).	Federal Statistical Office (2014c): Gesundheit. Kostennachweis der Krankenhäuser, 2013 (and previous volumes), Fachserie 12, Reihe 6.3, published on 11.11.2014, Wiesbaden.

Notes: The table shows our strategy to conduct data on inputs and outputs. Further information is available upon request.

TABLE S.4. PRODUCTIVITY RESULTS – II, 1993–2013

	Törnqvist				*Malmquist*		
	Input growth contributions[a]			*TFP*	*TFP*	*Thereof:*	
	Labor	*Capital*	*Intermediate goods*			*EFFCH*	*TECHCH*
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Panel A: Baseline (Labor: 3 types of staff, Capital: Capital stocks, Intermediates: 3 types of intermediates)							
All states							
Number of discharges	0.01%	0.34%	0.78%	-0.05%	-0.37%	0.30%	-0.67%
Quality index	0.01%	0.34%	0.78%	1.35%	0.85%	-0.14%	0.99%
Outcome	0.01%	0.34%	0.78%	1.30%	0.48%	0.16%	0.32%
West Germany[b]							
Number of discharges	0.00%	0.14%	0.75%	0.12%	0.28%	0.40%	-0.12%
Quality index	0.00%	0.14%	0.75%	0.99%	0.81%	-0.26%	1.07%
Outcome	0.00%	0.14%	0.75%	1.11%	1.09%	0.14%	0.95%
East Germany[c]							
Output	0.03%	0.79%	0.85%	-0.42%	-1.80%	0.09%	-1.89%
Quality	0.03%	0.79%	0.85%	2.14%	0.94%	0.13%	0.82%
Outcome	0.03%	0.79%	0.85%	1.72%	-0.86%	0.22%	-1.07%
Panel B: Sensitivity test (Labor: total staff, Capital: beds, Intermediates: total intermediates)							
All states							
Number of discharges	-0.18%	-0.12%	0.80%	0.59%	1.01%	0.32%	0.69%
Quality index	-0.18%	-0.12%	0.80%	1.35%	1.34%	-0.26%	1.60%
Outcome	-0.18%	-0.12%	0.80%	1.94%	2.35%	0.06%	2.29%
West Germany[b]							
Number of discharges	-0.17%	-0.13%	0.74%	0.57%	1.06%	0.36%	0.69%
Quality index	-0.17%	-0.13%	0.74%	0.99%	1.00%	-0.55%	1.55%
Outcome	-0.17%	-0.13%	0.74%	1.57%	2.06%	-0.19%	2.25%
East Germany[c]							
Number of discharges	-0.20%	-0.10%	0.92%	0.63%	0.92%	0.22%	0.70%
Quality index	-0.20%	-0.10%	0.92%	2.14%	2.07%	0.38%	1.69%
Outcome	-0.20%	-0.10%	0.92%	2.77%	2.99%	0.60%	2.39%

Notes: The table depicts the results of our TFP calculations. a) The sum of the growth contributions of all inputs and TFP is identical to the output growth rate. b) Including East Berlin. c) Excluding East Berlin.

TABLE S.5. CONTROL FOR CASE MIX INDEX, 2005–2013

	Outcome (quality-adjusted discharges)							
	Baseline (2005–2013)				*Control for Case Mix Index (2005–2013)*			
	Törnqvist	*Malmquist*			*Törnqvist*	*Malmquist*		
	TFP	*TFP*	*EFFCH*	*TECHCH*	*TFP*	*TFP*	*EFFCH*	*TECHCH*
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Policy								
Δln *Share of public hospitals*	-0.015**	-0.006	-0.022	0.016	-0.009	-0.002	-0.020	0.018
Δln *Share of private for-profit hospitals*	0.012	0.029	-0.034	0.063**	0.015	0.026	-0.034	0.059**
Δln *Hospital size*	0.142	-0.008	0.187	-0.195**	0.149	0.004	0.191*	-0.186*
Δln *Specialization*	0.627**	0.406	0.559	-0.153	0.672***	0.341	0.558*	-0.218*
Δln *Share of hospital funding*	0.000	-0.002	0.004	-0.007	0.000	-0.004	0.004	-0.008
Δln *Students of human medicine*	-0.033	-0.109	-0.024	-0.085	-0.035	-0.114	-0.026	-0.088
Left-wing health minister	-0.003	-0.007	-0.004	-0.003	-0.003	-0.006	-0.004	-0.002
Hospital policy induced								
Δln *Length of stay*	-1.948***	-2.103***	-1.779***	-0.324	-1.921***	-2.108***	-1.773***	-0.335
Δln *Occupancy rate*	0.061	0.060	0.157	-0.098	0.063	0.069	0.159	-0.090
Δln *Capital intensity*	0.109	-0.110	0.007	-0.116	0.126	-0.109	0.011	-0.120
Socio-economic conditions								
Δln *Share of intensive care days*	0.007	-0.059	-0.009	-0.050				
Δln *Case Mix Index*					-0.075	-0.043	-0.026	-0.016
Δln *Share of in-commut. patients from other states*	0.036	0.039	0.078	-0.039	0.036	0.028	0.076	-0.048
Δln *Share of out-commut. patients to other states*	0.046	-0.002	-0.079	0.077	0.050	0.004	-0.077	0.081
Δln *Out-patient physician per in-patient physician*	0.058	0.003	-0.135	0.138	0.044	-0.005	-0.140	0.135
Δln *Old-age dependency ratio*	0.094	-0.187	-0.022	-0.165	0.112	-0.183	-0.017	-0.166
Δln *Unemployment rate*	0.004	-0.005	-0.030	0.025	-0.004	-0.000	-0.031	0.031
Δln *GDP per capita*	0.109	-0.050	0.030	-0.080	0.094	-0.040	0.028	-0.068
Constant	-0.027***	-0.020*	-0.037***	0.017**	-0.026***	-0.021**	-0.037***	0.016**
Obs.	320	320	320	320	320	320	320	320
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared (within)	0.757	0.640	0.560	0.659	0.759	0.638	0.561	0.656

Notes: The table shows the results of second-stage regressions using outcome based TFP calculations of the period 2005–2013 as the dependent variable. All variables in growth rates (with exceptions of the dummy variables). Average state population 1993–2013 serves as regression weight. Significance levels (robust standard errors): *** 0.01, ** 0.05, * 0.10.

TABLE S.6. LENGTH OF STAY AS ADDITIONAL OUTPUT, 1993–2013

	Extended outcome (quality-adjusted discharges, length of stay)							
	Baseline				*Length of stay as additional output*			
	Törnqvist	*Malmquist*			*Törnqvist*	*Malmquist*		
	TFP	*TFP*	*EFFCH*	*TECHCH*	*TFP*	*TFP*	*EFFCH*	*TECHCH*
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Policy								
Δln *Share of public hospitals*	0.003	0.004	0.002	0.001	–	0.009	0.011	-0.002
Δln *Share of private for-profit hospitals*	0.008	-0.003	0.008	-0.011	–	0.001	0.015	-0.013
Δln *Hospital size*	0.144**	0.063	0.178***	-0.115**	–	0.065	0.127***	-0.062
Δln *Specialization*	0.452**	0.062	0.489**	-0.427**	–	0.415	0.759**	-0.344*
Δln *Share of hospital funding*	-0.004	0.003	0.001	0.001	–	-0.004	0.004	-0.008
Δln *Students of human medicine*	0.033	0.019	0.052	-0.033	–	0.064	0.071	-0.006
Left-wing health minister	-0.006	-0.006	-0.005	-0.001	–	-0.013**	-0.008	-0.005
Hospital policy induced								
Δln *Length of stay*	-0.888***	-1.179***	-0.777***	-0.402**	–	–	–	–
Δln *Occupancy rate*	0.336**	0.311*	0.317**	-0.006	–	0.005	0.056	-0.050
Δln *Capital intensity*	-0.017	-0.187**	-0.070	-0.117*	–	-0.065	0.026	-0.091
Socio-economic conditions								
Δln *Share of intensive care days*	-0.119*	-0.107	-0.022	-0.084*	–	-0.051	0.032	-0.083*
Δln *Share of in-commut. patients from other states*	-0.002	0.007	0.031	-0.023	–	0.012	0.032	-0.020
Δln *Share of out-commut. patients to other states*	0.020	0.050	-0.014	0.064**	–	0.082*	0.004	0.078**
Δln *Out-patient physician per in-patient physician*	0.112	0.188**	-0.069	0.257**	–	0.145**	-0.077	0.222**
Δln *Old-age dependency ratio*	0.629*	0.445	0.298	0.147	–	0.246	0.189	0.057
Δln *Unemployment rate*	-0.019	-0.013	0.034	-0.046	–	-0.031	0.007	-0.039
Δln *GDP per capita*	-0.112	-0.121	-0.092	-0.029	–	-0.320*	-0.188	-0.132
Constant	0.020	-0.003	-0.024	0.021	–	0.052**	0.009	0.042**
Obs.	320	320	320	320	–	320	320	320
Time fixed effects	Yes	Yes	Yes	Yes	–	Yes	Yes	Yes
State fixed effects	Yes	Yes	Yes	Yes	–	Yes	Yes	Yes
R-squared (within)	0.637	0.580	0.534	0.749	–	0.452	0.452	0.693

Notes: The table shows the results of second-stage regressions using outcome based TFP calculations as the dependent variable. Columns (1) to (4) reproduce our baseline findings. In columns (5) to (8), we treat the length of stay as an additional output and not as a second-stage explanatory variable. All variables in growth rates (with exceptions of the dummy variables). Average state population 1993–2013 serves as regression weight. Significance levels (robust standard errors): *** 0.01, ** 0.05, * 0.10.

TABLE S.7. WEST GERMANY AND EAST GERMANY – II, 1993–2013

	Number of discharges							
	West Germany[a]				*East Germany*[b]			
	Törnqvist	*Malmquist*			*Törnqvist*	*Malmquist*		
	TFP	*TFP*	*EFFCH*	*TECHCH*	*TFP*	*TFP*	*EFFCH*	*TECHCH*
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Policy								
Δln *Share of public hospitals*	0.001	0.007	0.006	0.001	-0.030	-0.076	-0.055	-0.021
Δln *Share of private for-profit hospitals*	0.014	0.009	-0.000	0.010	-0.002	-0.041	-0.015	-0.026
Δln *Hospital size*	0.093**	0.016	0.071*	-0.054*	0.169*	-0.036	0.109	-0.145
Δln *Specialization*	0.345**	0.307	0.370***	-0.063	0.128	-0.370	-0.029	-0.340
Δln *Share of hospital funding*	0.011	0.014	0.022**	-0.008	-0.000	-0.004	0.009	-0.013
Δln *Students of human medicine*	0.026	0.107*	0.074	0.033	0.188	-0.076	0.071	-0.147
Left-wing health minister	-0.000	0.003	0.003	-0.000	0.001	0.004	0.004	0.000
Hospital policy induced								
Δln *Length of stay*	-0.284***	-0.522***	-0.467***	-0.055	-0.761**	-0.709	-0.611**	-0.098
Δln *Occupancy rate*	0.206***	0.221*	0.272***	-0.051	0.331*	0.526*	0.206	0.320
Δln *Capital intensity*	0.206***	0.322***	0.192**	0.129	0.144*	0.168	0.078	0.090
Socio-economic conditions								
Δln *Share of intensive care days*	-0.090*	-0.062	-0.013	-0.049	-0.010	-0.047	-0.005	-0.042
Δln *Share of in-commut. patients from other states*	0.012	0.019	0.027	-0.008	0.012	0.041	0.006	0.035
Δln *Share of out-commut. patients to other states*	0.010	-0.004	-0.016	0.012	-0.058	0.061	-0.003	0.065
Δln *Out-patient physician per in-patient physician*	-0.013	0.034	-0.047	0.081	-0.064	-0.121	-0.141	0.020
Δln *Old-age dependency ratio*	0.457	0.503	0.584	-0.082	0.081	-0.870	0.026	-0.896
Δln *Unemployment rate*	-0.031	-0.067***	-0.049*	-0.018	0.018	0.339**	0.113	0.226**
Δln *GDP per capita*	-0.114	-0.156	-0.092	-0.064	-0.141	-0.021	0.089	-0.109
Constant	-0.004	-0.004	-0.001	-0.002	-0.062**	-0.031	-0.045	0.014
Obs.	220	220	220	220	100	100	100	100
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared (within)	0.670	0.609	0.424	0.672	0.722	0.504	0.410	0.596

Notes: The table shows the results of second-stage regressions by subsamples (11 West German states, 5 East German states) using discharges based TFP calculations as the dependent variable. All variables in growth rates (with exceptions of the dummy variables). Average state population 1993–2013 serves as regression weight. a) Including East Berlin. b) Excluding East Berlin. Significance levels (robust standard errors): *** 0.01, ** 0.05, * 0.10.

TABLE S.8. WEST GERMANY AND EAST GERMANY – III, 1993–2013

	Quality index							
	West Germany[a]				*East Germany*[b]			
	Törnqvist	*Malmquist*			*Törnqvist*	*Malmquist*		
	TFP	*TFP*	*EFFCH*	*TECHCH*	*TFP*	*TFP*	*EFFCH*	*TECHCH*
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Policy								
Δln *Share of public hospitals*	0.004	0.001	-0.004	0.005	0.063	0.087**	0.054	0.034
Δln *Share of private for-profit hospitals*	0.011	0.001	0.011	-0.011	0.019	0.036**	0.025	0.010
Δln *Hospital size*	0.106*	0.101	0.134**	-0.033	-0.118	-0.180**	-0.129	-0.051
Δln *Specialization*	0.437***	0.227	0.600**	-0.373	-0.125	-0.612*	-0.041	-0.571
Δln *Share of hospital funding*	-0.009	-0.001	-0.015	0.014*	-0.019**	-0.025	-0.021	-0.004
Δln *Students of human medicine*	0.024	-0.025	0.054	-0.079	0.039	0.204	0.066	0.137
Left-wing health minister	-0.011***	-0.013***	-0.013***	-0.000	0.002	-0.001	-0.002	0.000
Hospital policy induced								
Δln *Length of stay*	-0.436**	-0.532**	-0.259	-0.272*	-0.593*	-0.505	-0.192	-0.313
Δln *Occupancy rate*	0.133	0.130	0.093	0.037	0.218	0.148	0.124	0.025
Δln *Capital intensity*	0.057	-0.135	-0.035	-0.099	-0.162	-0.414**	-0.319*	-0.095
Socio-economic conditions								
Δln *Share of intensive care days*	-0.111*	-0.121	-0.077	-0.044	-0.008	0.018	0.042	-0.024
Δln *Share of in-commut. patients from other states*	0.020	0.027	0.032	-0.004	-0.026**	-0.048**	0.008	-0.056
Δln *Share of out-commut. patients to other states*	0.040	0.047	-0.017	0.063*	0.061	0.182**	0.118	0.064
Δln *Out-patient physician per in-patient physician*	0.034	0.099	-0.124	0.222**	0.012	-0.097	-0.141	0.044
Δln *Old-age dependency ratio*	0.364**	0.402*	0.215	0.187	-0.239	-0.012	-0.685	0.673
Δln *Unemployment rate*	0.003	0.024	0.062	-0.038	0.038	-0.035	-0.126	0.091
Δln *GDP per capita*	0.057	0.090	0.017	0.073	-0.086	-0.355**	-0.502	0.147
Constant	0.017**	0.013*	-0.000	0.013**	0.063*	0.093*	0.076	0.017
Obs.	220	220	220	220	100	100	100	100
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared (within)	0.627	0.575	0.534	0.773	0.704	0.676	0.532	0.757

Notes: The table shows the results of second-stage regressions by subsamples (11 West German states, 5 East German states) using quality index based TFP calculations as the dependent variable. All variables in growth rates (with exceptions of the dummy variables). Average state population 1993–2013 serves as regression weight. a) Including East Berlin. b) Excluding East Berlin. Significance levels (robust standard errors): *** 0.01, ** 0.05, * 0.10.

TABLE S.9. DIFFERENT REIMBURSEMENT SCHEMES – II

	Number of discharges											
	Reimbursement scheme								*Difference*			
	Fixed daily rates (1993–2003)				*DRG (2004–2013)*							
	Törnqvist	*Malmquist*			*Törnqvist*	*Malmquist*			*Törnqvist*	*Malmquist*		
	TFP	*TFP*	*EFFCH*	*TECHCH*	*TFP*	*TFP*	*EFFCH*	*TECHCH*	*TFP*	*TFP*	*EFFCH*	*TECHCH*
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Policy												
Δln *Share of public hospitals*	0.091***	0.017	0.090**	-0.073**	0.037	-0.070	-0.020	-0.050	-0.054	-0.087	-0.110*	0.023
Δln *Share of private for-profit hospitals*	0.003	0.005	0.011	-0.007	-0.007	0.000	-0.008	0.008	-0.011	-0.004	-0.019	0.015
Δln *Hospital size*	0.003	-0.010	-0.001	-0.009	0.029	0.047**	-0.006	0.053*	0.026	0.057*	-0.005	0.062**
Δln *Specialization*	0.472**	0.596**	0.500**	0.096	0.163	-0.111	0.279**	-0.390**	-0.309	-0.707***	-0.221	-0.486**
Δln *Share of hospital funding*	0.002	0.003	0.019***	-0.016**	0.002	0.003	0.005	-0.003	0.001	-0.000	-0.013	0.013
Δln *Students of human medicine*	0.032	0.076	0.061	0.015	-0.027	-0.068	-0.007	-0.060	-0.059	-0.144	-0.068	-0.075
Left-wing health minister	0.001	0.009	0.005	0.004	0.002	-0.000	0.004	-0.004	0.001	-0.009**	-0.001	-0.008**
Hospital policy induced												
Δln *Length of stay*	-0.248**	-0.518***	-0.480***	-0.038	-0.846***	-0.906***	-0.898***	-0.008	-0.598***	-0.388	-0.418	0.030
Δln *Occupancy rate*	0.200***	0.245	0.276	-0.031	0.188*	0.079	0.101	-0.022	-0.013	-0.166	-0.175	0.009
Δln *Capital intensity*	0.053	0.008	-0.013	0.021	0.067	0.090	0.066	0.024	0.014	0.082	0.078	0.003
Socio-economic conditions												
Δln *Share of intensive care days*	-0.059	-0.037	-0.019	-0.018	0.009	-0.000	0.079**	-0.080	0.068	0.037	0.099**	-0.062
Δln *Share of in-commut. patients from other states*	0.007	0.004	0.001	0.003	-0.010	0.008	0.034	-0.026	-0.017	0.003	0.033	-0.030
Δln *Share of out-commut. patients to other states*	-0.057*	-0.038	-0.053*	0.015	0.040**	0.055	0.045	0.010	0.096**	0.093	0.098	-0.005
Δln *Out-patient physician per in-patient physician*	0.006	0.091	0.032	0.059	0.108**	0.153*	-0.064	0.217**	0.102	0.062	-0.096	0.158
Δln *Old-age dependency ratio*	0.292	0.089	0.466	-0.376	0.509**	0.161	0.289	-0.128	0.217	0.072	-0.176	0.248
Δln *Unemployment rate*	-0.000	0.022	0.018	0.004	-0.035	-0.023	-0.007	-0.016	-0.035	-0.045	-0.025	-0.020
Δln *GDP per capita*	-0.246*	-0.193	-0.030	-0.164	-0.094*	-0.250**	-0.144	-0.107	0.153	-0.057	-0.114	0.057
Obs.	–	–	–	–	–	–	–	–	320	320	320	320
Time fixed effects	–	–	–	–	–	–	–	–	Yes	Yes	Yes	Yes
State fixed effects	–	–	–	–	–	–	–	–	Yes	Yes	Yes	Yes
R-squared (within)	–	–	–	–	–	–	–	–	0.668	0.531	0.411	0.614

Notes: The table shows the results of second-stage regressions by subperiods using discharges based TFP calculations as the dependent variable. Results come from a model using the interaction of policy measures and a dummy which equals one for activity-based hospital funding (2003–2013), and zero otherwise. Columns (1)–(4) show the effects for the period prior the introduction of activity-based hospital funding (DRG) (1993–2003), Columns (5)–(8) show the effects for the period afterwards. Columns (9) to (12) takes the differences between both periods. Coefficients for the constant and the interaction dummies are left out. All variables in growth rates (with exceptions of the dummy variables). Average state population 1993–2013 serves as regression weight. Significance levels (robust standard errors): *** 0.01, ** 0.05, * 0.10.

TABLE S.10. DIFFERENT REIMBURSEMENT SCHEMES – III

	Quality index											
	Reimbursement scheme								*Difference*			
	Fixed daily rates (1993–2003)				*DRG (2004–2013)*							
	Törnqvist	*Malmquist*			*Törnqvist*	*Malmquist*			*Törnqvist*	*Malmquist*		
	TFP	*TFP*	*EFFCH*	*TECHCH*	*TFP*	*TFP*	*EFFCH*	*TECHCH*	*TFP*	*TFP*	*EFFCH*	*TECHCH*
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Policy												
Δln *Share of public hospitals*	0.039	0.052	0.136**	-0.084*	0.079	0.070	0.128**	-0.058	0.040	0.019	-0.007	0.026
Δln *Share of private for-profit hospitals*	0.017	0.014	0.025	-0.011	-0.001	-0.007	-0.017	0.010	-0.019	-0.021	-0.042	0.021
Δln *Hospital size*	0.002	0.003	0.032*	-0.029**	0.030**	0.010	-0.019	0.029	0.029**	0.007	-0.051	0.058*
Δln *Specialization*	-0.022	-0.322	-0.052	-0.270	0.613**	0.400	0.513	-0.113	0.635	0.722	0.565	0.157
Δln *Share of hospital funding*	-0.014	-0.016	-0.019	0.004	-0.004	0.003	-0.008	0.011	0.010	0.019	0.012	0.007
Δln *Students of human medicine*	0.015	0.027	0.086	-0.059	0.018	-0.001	0.007	-0.008	0.003	-0.028	-0.079	0.051
Left-wing health minister	-0.009***	-0.013**	-0.013**	-0.000	-0.005	-0.007	-0.005	-0.002	0.004	0.006	0.008*	-0.002
Hospital policy induced												
Δln *Length of stay*	-0.389**	-0.449**	-0.166	-0.283***	-0.831***	-0.981***	-0.414	-0.567**	-0.441**	-0.532**	-0.248	-0.284
Δln *Occupancy rate*	0.274	0.309	0.373**	-0.063	0.006	-0.034	-0.102	0.068	-0.268	-0.343	-0.475	0.132
Δln *Capital intensity*	-0.026	-0.212***	-0.053	-0.159***	0.025	-0.210**	-0.173	-0.037	0.051	0.002	-0.120	0.122
Socio-economic conditions												
Δln *Share of intensive care days*	-0.040	-0.032	0.010	-0.042	-0.075	-0.108**	-0.071**	-0.037	-0.035	-0.076	-0.081	0.005
Δln *Share of in-commut. patients from other states*	-0.002	0.011	0.020	-0.009	0.025	0.008	0.002	0.006	0.027	-0.002	-0.017	0.015
Δln *Share of out-commut. patients to other states*	0.013	0.041	0.086***	-0.045	0.050	0.043	-0.077**	0.120***	0.036	0.002	-0.163***	0.165***
Δln *Out-patient physician per in-patient physician*	0.001	0.044	-0.183	0.227*	0.131**	0.106	0.034	0.073	0.131	0.062	0.217	-0.155
Δln *Old-age dependency ratio*	0.419	0.393	-0.028	0.421	0.086	0.167	-0.151	0.319	-0.333	-0.226	-0.124	-0.102
Δln *Unemployment rate*	0.035	0.028	0.085	-0.057	-0.016	-0.016	-0.007	-0.009	-0.051	-0.045	-0.092	0.048
Δln *GDP per capita*	0.025	0.089	-0.186	0.275**	0.074	0.098	0.085	0.013	0.049	0.009	0.271	-0.262
Obs.	–	–	–	–	–	–	–	–	320	320	320	320
Time fixed effects	–	–	–	–	–	–	–	–	Yes	Yes	Yes	Yes
State fixed effects	–	–	–	–	–	–	–	–	Yes	Yes	Yes	Yes
R-squared (within)	–	–	–	–	–	–	–	–	0.640	0.566	0.514	0.762

Notes: The table shows the results of second-stage regressions by subperiods using quality index based TFP calculations as the dependent variable. Results come from a model using the interaction of policy measures and a dummy which equals one for activity-based hospital funding (2003–2013), and zero otherwise. Columns (1)–(4) show the effects for the period prior the introduction of activity-based hospital funding (DRG) (1993–2003), Columns (5)–(8) show the effects for the period afterwards. Columns (9) to (12) takes the differences between both periods. Coefficients for the constant and the interaction dummies are left out. All variables in growth rates (with exceptions of the dummy variables). Average state population 1993–2013 serves as regression weight. Significance levels (robust standard errors): *** 0.01, ** 0.05, * 0.10.

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